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AIR FORCE SYSTEMS COMMAND

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(Selected Articles)

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TITLE: OUTPUT CHARACTERISTICS OF COPPER VAPOR LASER DEVICE STRETCH AMPLIFICATION AND DOUBLE PASS AMPLIFICATION

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SUMMARY In the oscillation-amplification system of copper vapor laser devices, we opted for the use of stretched or widened pulse width input amplification as well as double pass amplification technology. The output power is capable, as compared to the unwidened or unstretched and travelling wave amplification output powers, of being higher by 7% and 8% respectively. The amount of fluctuation or jitter of the output optical waveform of copper vapor laser devices relative to input optical waveforms was ± 4.0ns., while the amount of fluctuation or jitter between the two oscillators was ± 9.0ns.

KEY TERMS Copper Vapor Laser, Amplifier, Synchronism

I. INTRODUCTION

In order to raise the output power of copper vapor laser devices, and, in conjunction with that, improve their directionality, we opted for the use of laser systems with non-stable cavity oscillation traveling wave amplification output. It is possible, compared to single oscillators, to raise output power more than 15%. Moreover, it is also possible to go through alterations in the multiplication rate, causing the output light after amplification to approach diffraction limits[1-3]. M. Amit and others, in experiments, discovered that widened input optical pulse width is advantageous to raising the output power of amplifiers[4]. With regard to this, we carried out detailed experimental research. This pointed out that widened input optical pulse widths are in order to restrain the spontaneous radiation of amplifiers within a relatively wide range of time, causing an even greater number of reverse particles to become laser output. Following this, we, for the first time, in copper vapor laser devices, opted for the use of double pass amplifier technology in order to increase the effective length of the area of excitation, adequately extracting the number of reverse particles within the volume of the space. In conjunction with this, we took the fluctuation or jitter waveforms between two oscillation devices and between oscillation amplifiers and made comparisons, facilitating the raising of the synchronous precision of multipath laser systems.

II. EXPERIMENTAL CONDITIONS AND EXPERIMENTAL EQUIPMENT

The experiments opted for the use of two self-heating type pure copper laser devices with the same structure. The interior diameter of amplifier tubes was D = 2.6cm. The electrode distance was 89.0cm. They were filled with Ne gas to act as the buffer gas. The gas pressure was between 20-50 Torr. The oscillator devices opted for the use of multiplication rates of M=10 telescopic type non-stable cavities. Use was made of 45° full reflection flat plates to act as the output coupling mirrors.

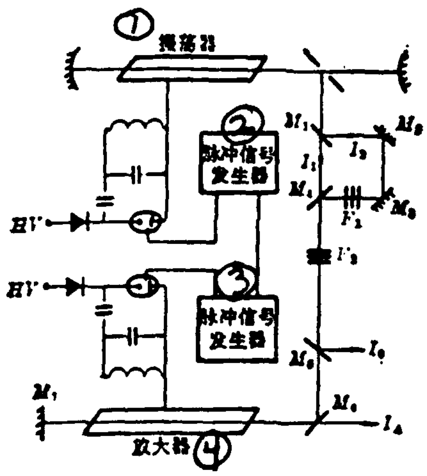

Fig.1 Schematic Diagram of the Experimental Equipment (1) Oscillator (2) Pulse Signal Generator (3) Pulse Signal Generator (4) Amplifier

The experiments opted for the use of shift type discharge circuitry excitation. Charging capacitance was 5000 pf. Sharpened capacitance was 1000 pf. The frequency of repetition was 6kHz. The operating voltage range was 5-6 kV. The corresponding average voltage was 0.45-0.70 A. The thyratron tube was a domestically produced 4050A model. Using oscillator pulse signals to act as exterior contact signals for amplifier pulse signals, in this way, one adjusts the

XC-46 Model pulse signal generator delay times. It is then possible to maintain synchronicity between oscillators and amplifiers. Making use of the SD2490 Model digital type power meter to calculate absolute powers, one uses a fast reacting electroptical diode (PIN) to act as the receiver device. The laser waveform is displayed by observing the 100 MC general purpose oscilloscope.

The experimental equipment was as shown in Fig.1. M_1 is a plated membrane flat plate with a 23% reflection rate. M_2, M_3, and M_7 are all completely reflecting flat plates. M_4 is a half-reflecting half-transmitting flat plate. M_5 and M_6 are both flat plates of glass. F_1 and F_2 are light filtering slabs. F_1 is capable of guaranteeing that the light strengths of I_1 and I_2 are equal to each other after they pass through M_4. F_2 is capable of guaranteeing that the light strength after I_1 and I_2 combine together is equal to the light strength after I_1 passes through M_4 independently.

III. STANDING WAVE AMPLIFICATION AFTER THE INPUT OF STRETCHED OPTICAL PULSE WIDTHS

Due to the fact that copper vapor laser devices are high gain lasers, one normally opts for the use of high loss resonance cavity coupling output. Because of this, oscillator threshold values are relatively high. Output light pulse widths are relatively narrow. Measurement results clearly demonstrate that oscillator output light pulse widths are 20-30ns, while amplified spontaneous radiation pulse widths were approximately 30-40ns. As a result of this, increasing input light pulse widths is then capable of restraining, within the wider time range, the amplified spontaneous radiation. Therefore, this causes even more numerous reverse or inverted particles turning into laser output. Because of this, one opts for the use of experimental equipment like that shown in Fig.1. Moving out fully reflecting mirror M_7, one then forms a traveling wave amplification. Going through alterations in the course of the light between I_1 and I_2, it is then possible to obtain output light for different synthesizing pulse widths. Experiments were carried out with optimal

delay times. Input powers were 630mW. At this time, amplifiers were already placed in a saturation state[5]. Experimental results are shown in Fig.2. When input light pulse widths are increased from 20ns to 36ns, output power increases from 3.51 W to 3.75 W. The efficiency ($\eta = \eta(P_2 - P_1)/P_1$) went up 6.8%. From Fig.2 it is possible to see that, following along with repeated increases in input light pulse width, output powers are also capable of increasing a step further. However, there is already a tendency toward saturation.

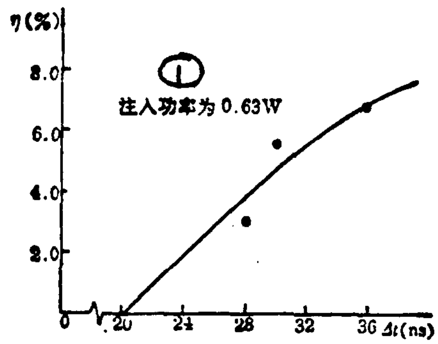

Fig.2 Pulse Width and Power Relationships. P_1 and P_2 are respectively traveling wave amplification powers before widths are increased and after widths are increased. (1) Injection power is 0.63 W.

Fig.3 Waveform Transverse Coordinates 20ns/div for Input Light (Above) and Amplified Light (Below)

Fig.3 is the waveforms for input light (above) and amplified light (below) when pulse width is increased to 36ns. In the Fig., the amplified light waveform is smoother than the input light waveform. This is because, at this time, the input light power (630W) is very much greater than the input light power (approximately 220W) when amplifiers reach saturation output. Because of this, in laser waveforms in which input light impulse peak values are over 1/3, all will reach saturation amplification.

IV. DOUBLE PASS AMPLIFICATION

Due to the fact that copper vapor laser devices are high gain, it follows as a result that we, in copper vapor lasers, opt for the use of double or dual pass amplification techniques, taking increases in the length of the effective activity area or zone to adequately extract the number of reverse or inverse particles within the volume of the space. In Fig.1, after blocking out the I_2 light, initial measurements were made of the relationship curve (Fig.4) for dual pass amplification and traveling wave amplification output power as they follow along with changes in input power. It is obvious and can be clearly seen that the strong point of dual pass amplification, besides the output power being raised 8% higher than that of traveling wave amplification, also lies in the very, very great drop in the requirement for input light power. In order to reach a 95% calculation of saturation output power, traveling wave amplification input light power required 250mW, while dual pass amplification input light power only requires 35mW. A seven fold reduction.

In experiments, it was also discovered that, when one reaches optimum delay times, dual pass amplification input light will, compared to traveling wave amplification input light, shift forward 3-4ns. This corresponds exactly with a laser device length of 1.5m. From this, one can learn that input light first goes through a course of preamplification. After that, it, again, goes through a course of power amplification. Because of this, there is a very, very large drop in the requirement for input light power. At the same time, adequate extraction is made of the number of reverse or inverse particles within the volume of the space.

Fig.5 clearly shows that dual pass amplification light pulses and impulse light pulse widths are basically equal. Moreover, the waveform wave shapes are also similar to each other, presenting a small, sharp peak form. However, going through comparisons of the amplitude multiplication rates of three individual small sharp peaks, it is possible to discover that the amplitude multiplication rates for the forward edge and center sections of light wave forms in dual pass amplification are slightly larger than th amplitude multiplication rates for trailing edges. This is due to the fact that when trailing edges enter the area of activity or activation, the first portion of the light goes through the zone of activation for a second time. The two simultaneously compete as a cause of the number of inverse particles. Besides this, because the power of the input light is only several tens of mW, the first course or pass is preamplification. The pulse peaks and valleys almost reach the same amplitude multiplication rate. Due to the fact that the interval between the various peaks of the input light is just equal to $2L/c \approx 13ns$, L is the cavity or chamber length of the oscillators. Because of this, when the first peak valley enters the amplifier zone of activation for the first time, the first peak is just entering the zone of activation the second time, while, when the first peak valley is entering the zone of activation the second time, the second peak is just entering the zone of activation the first time. The two compete in inverse particle number. The result is to cause the pulse wave form modulation depth to increase by contrast.

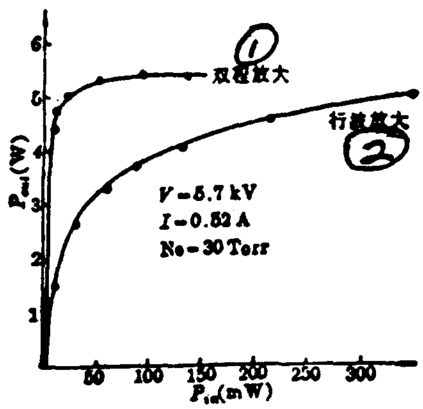

Fig.4 Relationship Curves for Traveling Wave Amplification and Dual Pass Amplification Output Powers Following Changes in the Power of Injected Light (1) Dual Pass Amplification (2) Traveling Wave Amplification

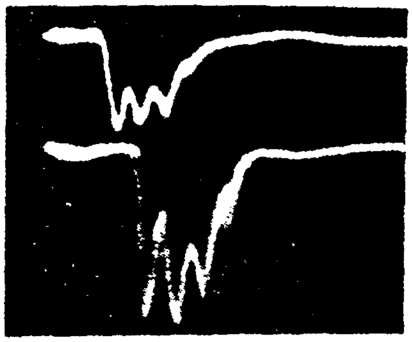

Fig.5 Input Light Wave Forms (Above) and Dual Pass Amplification Light Wave Forms (Below) (20ns/div)

Finally, measurements were done of the directionality of dual pass amplification output light. Its angle of divergence and the angle of divergence of input light are the same at 1.2 mrad (taking an 80% calculation of output power). 4

V. FLUCTUATIONS IN AMPLIFICATION LIGHT WAVEFORMS CORRESPONDING TO OSCILLATION LIGHT WAVEFORMS

Copper vapor laser devices all opt for the use of high repetition frequency thyratron tube discharges. Normally, in the period of discharge, there exists a certain amount of dispersion. Speaking with regard to the oscillator devices, this type of dispersion only effects the order of the periods of outgoing light. It certainly does not influence the magnitude of laser power. However, acting as an amplifier device, this type of dispersion will not only give pulse waveforms a certain attendant amount of deformity; moreover, it will cause laser power to fluctuate in the vicinity of maximum power.

In laser separation isotope technology, multiple path lasers have various types of composite forms, for example, using a single signal source and various independent oscillators, or using one stage to act as an oscillation device, the remainder as parallel amplifiers. We compared the synchronous precision of the two types of composite forms

described above. Fig.6 is the laser waveforms sketched on the oscilloscope. The oscilloscope opts for the use of A triggering B mode operations. In Fig.6(a) the first waveform is an original oscillator output waveform. Due to the fact that the pulse repetition rate is 6kHz, a result is that, on the oscilloscope, one sees the superposition of a thousand iterations of the pulse waveforms above. In Fig.6, the front pulse waveform is clear. The explanation is that, within a short period of time, the laser reproducability or representative nature is very good. This is due to the fact that the oscilloscope triggering form causes the head pulse waveform to be "fixed" in its initial location. In reality, the through conductance time of the thyratron tube for each laser device, in all cases, possesses a certain amount of divergence. Because of this, we, in Fig.6(a), can see that the amount of fluctuation or jitter in the second waveform, in reality, is the sum of the fluctuation movements of the through conductance times of two thyratron tubes. From Fig.6(a), the amount of fluctuation or jitter movement calculated for the second waveform relative to the first waveform is $\pm$ 9.0ns. From this, it is possible to know that the average amount of divergence in the through conductance times for each thyratron tube is $\pm$ 4.5ns. From Fig.6(b), the amount of fluctuation or jitter for the second wave form relative to the first waveform is only $\pm$ 4.0ns.

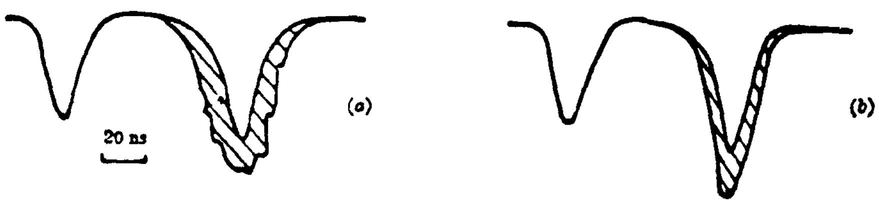

Fig.6 (a) Laser Waveforms for Two Oscillators (b) Laser Waveforms for Oscillation Amplifiers

Due to the fact that amplifier output light is obtained precisely from input light after it goes through the amplifiers, the amount of

divergence between the through conductance times of two thyratron tubes only causes the input light to be placed in the vicinity of optimum delay time, giving rise to waveform distortions, or leading edge steepening, or trailing edge steepening. Moreover, the larger the amount of divergence is, the larger the changes in the peak values of the waveforms also are. Because of this, it is possible to know that the fluctuation movements or jitter of amplified light waveforms are the results of the superposition of a good number of distorted waveforms. These are completely different from the nature of the properties of wave form fluctuation movements or jitter (superposed after translation) between two oscillators. This leads to the amount of fluctuation or jitter in amplified light waveforms relative to oscillation light waveforms to be smaller by over half than the waveform fluctuation movement or jitter between two oscillators. Because of this, in multipath laser isotope separation technology, it is advantageous to opt for the use of oscillation-amplification systems in raising separation efficiency.

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TECHNOLOGY SEMINAR CALLED IN SUZHOU ON APPLICATIONS OF NEODYMIUM GLASS LASER DEVICES

Zhou Wenguan

As is known by everyone, neodymium glass is one type of operating medium which is commonly used in laser devices. However, the thermoptical characteristics of the silicate glass which was used in the past were inferior. Threshold values were relatively high while efficiency was relatively low. Because of this, the range of its use suffered from a certain limitation. At the present time, outside of China, the use of phosphate neodymium glass is universal. Because this type of glass has a large cross section to recieve excitation radiation, its rate of nonlinear refraction is small. Threshold values are low. Efficiency is high. Because of this, in laser plasma body research, laser nuclear fusion, as well as laser processing, and other similar applications, it possesses broad prospects.

However, the resistance to moisture of the surface of phosphate glass is slightly poor. The mechanical strength is somewhat low. Thermal expansion coefficients are large. If one makes extended use of silicate glass in operating conditions, high power light pumps, for inappropriately long periods of time, then, make it easy to give rise to thermal bursting. The operating field should also maintain interference in order to avoid the end surfaces growing thin protuberances. The light collection cavity's design and lamp-rod matching are also important conditions in making the instruments optimal.

In order to add strength to the relationship between units involved with the test manufacture and use of neodymium glass, the Chinese Academy of Sciences, Shanghai Opticomechanics Institute, on August 10, 1989, in Suzhou, called a technological research symposium on applications of neodymium glass laser devices. There were over 30 representatives who attended the conference. At the meeting, the relevent laboratories of the institute in question introduced the important characteristics of phosphate glass, laser properties, and so

on. Using units introduced phosphate laser devices boring holes in various types of metallic, nonmetallic, and magnetic materials--in particular, the status of the use of boring deep holes. The representatives carried on sincere discussions concerning how to raise a step further the quality of phosphate glass, improve the operating conditions of laser instruments, and broaden the range of their applications.

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